U. S. DEPARTMENT OF AGRICULTURE.

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THE COTTON BOLLWORM:

AN ACCOUNT OF THE INSECT, WITH RESULTS OF EXPERIMENTS IN 1903.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., January 18, 1904.

SIR: I have the honor to transmit herewith the manuscript of an account of the cotton bollworm, based on investigations conducted during the year 1903, according to special Congressional appropriation made for the purpose, and prepared by Mr. A. L. Quaintance, agent in charge of cotton bollworm investigations. The bollworm is one of the most destructive insects of the United States, and, as the information furnished in this article is confidently believed to be of much value to cotton growers, it is urged that it be given immediate publication.

Respectfully,

L. O. HOWARD,
Entomologist.

Hon. JAMES WILSON,
Secretary of Agriculture.

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INTRODUCTORY.

The so-called bollworm, the larva of the moth *Heliothis armiger* Hbn., has long been known as an important enemy of cotton. As early as 1841 it was found in the cotton fields around Tallahassee, Fla., where, in the course of a few years, it became quite destructive. It was seriously injurious to cotton in Alabama in 1847, in Mississippi in 1850, and in Louisiana in 1867. By 1879 it had become the principal insect enemy of cotton in Texas, and at the present time ranks second in importance only to the Mexican cotton boll weevil.

This insect was early the subject of investigation by the General Government. In the Patent Office Agricultural Report for 1854, Townend Glover gave an excellent article on the bollworm, detailing the principal points in its natural history. The results of the work of the Division of Entomology and of the United States Entomological Commission on this insect from about 1878 to 1881 are displayed in Comstock's Report on Cotton Insects, and in the Fourth Report of the United States Entomological Commission by Professor Riley. A supplementary investigation of the bollworm was made by Professor Mally, under the direction of the Division of Entomology, in the early nineties, and the results are set forth in Bulletins 24 and 29 (old series), issued in 1891 and 1893 respectively. More recently (1897) an account of this species has been distributed in Farmers' Bulletin No. 47 (Insects Affecting the Cotton Plant), by Dr. L. O. Howard.

As a result of these several publications a knowledge of the bollworm's life and habits, and of the best methods to be employed in its control, has been quite widely disseminated. Nevertheless, little if any effort has been made by planters during the many years of bollworm injury to check its ravages, and, along with the increased cultivation of cotton from year to year, often to the exclusion of any other crop, the losses from this insect have tended to increase rather than to diminish.

The considerable injury done by the bollworm during the past two or three years, notably in certain portions of Texas, led to provision by Congress for a further investigation of this insect by the Division of Entomology, and the writer was detailed to the work in Texas.

Headquarters were established at Victoria, where office and other facilities were available in the laboratory of the force engaged in investigations relating to the cotton boll weevil. Such laboratory investigations as were possible were conducted, but special attention was given to field work, this being considered of more importance in view of the many facts already known about the life and habits of the bollworm. Through the cooperation of the agent charged with boll-weevil investigations, arrangements were made for the growing of cotton on the contract plan with planters at Calvert, Willspoint, and Hetty, Tex., including in all 140 acres. The locations chosen are fairly typical of the respective sections, and in two the bollworm had been especially destructive the year previous.

INJURY IN 1903.

Aside from certain isolated localities here and there in the cotton belt, bollworm injury during 1903 appears to have been confined mostly to Texas and to the southern portion of Indian Territory. The accompanying map (fig. 1), indicates the area most seriously ravaged in Texas. Injury was especially severe in some of the north Texas counties, as Fannin, Lamar, Delta, Hunt, Hopkins, Kaufman, and Van Zandt; and also in the central Texas counties, Navarro, Henderson, Limestone, Falls, Bell, and Robertson, the loss in each of these counties being variously estimated at from 20 to 60 per cent of the crop.

It is hard to arrive at even an approximate estimate of the loss, owing to the difficulty of securing trustworthy data. The tendency to exaggerate losses from insects is well known, as is also the tendency to attribute to insect depredations the disastrous effects which may result from changes in the weather or from other conditions. The shaded portion of the map includes the principal cotton-producing area of the State, from which, in 1902, came approximately three-fourths of the total cotton product of Texas. Throughout this area bollworm ravages were reported as more or less extensive in 1903. A conservative estimate of the injury, based on data secured from various sources and from personal observations, it is believed would be approximately 90,000 bales, which, at a valuation of $50 per bale, would mean a loss of $4,500,000. If to this amount be added the value of the cotton seed the total loss sustained would easily exceed $5,000,000.

According to the estimate of Professor Mally, bollworm injury in Texas in 1902 amounted to approximately $4,750,000, and the area most seriously ravaged coincides rather closely with that injured in 1903. It may also be said that the shaded portion of the map marks approximately the area of greatest corn production, and the simple rotation of corn with cotton, so largely practiced, has undoubtedly contributed to the seriousness of the bollworm situation at the present time.

DISTRIBUTION.

The bollworm has a world-wide distribution. It occurs throughout most of the United States, and is reported from many localities in Central and South America and the West Indies. It is recorded from various countries of Europe, as England, France, Germany, Spain,

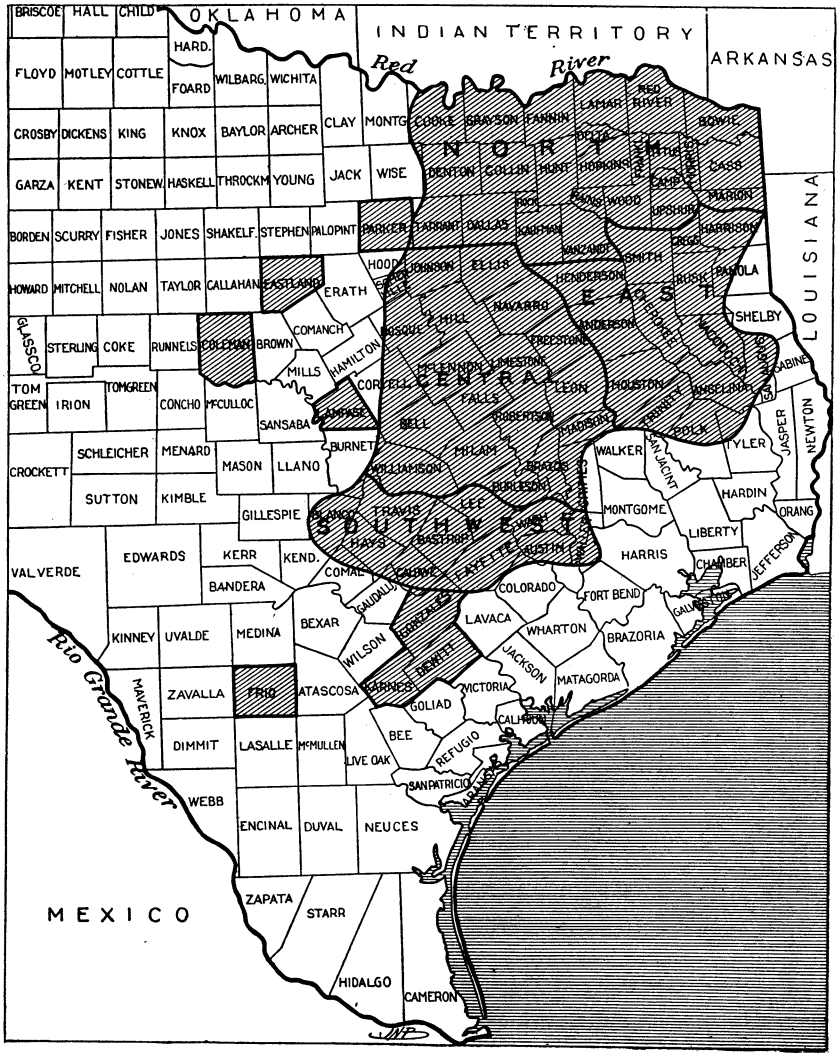

FIG. 1.—Map of Texas, showing territory ravaged by bollworm in 1903.

and Russia; and also from the Canaries, Kongo, South Africa, New Zealand, Australia, Ceylon, Java, India, Japan, China, and Hawaii. It is not possible to determine the origin of the bollworm.

It is of interest to note that the species was described from Europe in 1796, while its first recorded occurrence in the United States was in 1841.

GENERAL APPEARANCE AND LIFE CYCLE.

Throughout this bulletin the common appellation of this insect in the cotton belt, namely, the bollworm, is adhered to. It need hardly be explained that the larva known variously as the budworm of corn, the tassel worm, corn earworm, and tomato fruitworm, is identical with the cotton bollworm.

The egg.—Bollworm eggs may easily be detected with the unaided eye, and may be most readily found on the fresh silk of corn. They are oval in shape, whitish or yellowish in color, and average in diameter about 0.45^{mm} to 0.5^{mm}. Examined under a hand lens, they are seen to be sculptured with polar ribs and cross furrows like those on the eggs producing the cotton caterpillar. The eggs of this latter species, however, are much flatter and greenish in color, and are, therefore, not likely to be confused with those of the species under consideration. The eggs of the bollworm hatch in from two and one-half to six days, depending on the temperature.

The larva.—The insect is most commonly known in this, the bollworm, stage. It is only during this larval existence that injury is inflicted. Newly hatched bollworms are very small and are usually quite overlooked by planters until they are of sufficient size to attack the buds, squares, and young bolls. As the larvæ grow, a remarkable diversity of color and markings may become apparent, ranging from whitish or greenish without decided markings of any kind, to individuals which are rose colored or almost black, with distinct spots and dorsal and lateral longitudinal stripes. This color variation has been the source of some confusion as to the identity of the larva, particularly when on other plants than cotton. The bollworm is a voracious feeder and grows rapidly, completing its growth during summer in from twelve to fifteen days. During the cool weather of spring and fall its rate of growth is much slower.

A full-grown larva measures from 1¼ to 1½ inches in length. The body is stout and tapers slightly toward the head and caudal extremities. In the darker individuals the markings consist of a narrow, dorsal, central, longitudinal, black stripe, centered with a fine white line. On each side of the body, including the breathing pores, is a broad, whitish, lateral stripe, extending from the head to the last segment. Just above this lateral stripe is a broad, dusky, longitudinal band, and between this latter and the central dorsal stripe is a broad whitish band, often marked with fine whitish lines, but so delicate as not to interfere with the general color of the body. On the more central body segments are usually eight black spots, extending in an

irregular transverse line from one stigmatal stripe to the other. The breathing pores are black in color, the head brownish, and the entire ventral portion light.

The pupa.—When full grown the bollworm leaves its food plant, burrows below the soil surface some 2 to 5 inches, and constructs a more or less upright cell, reaching to near the surface of the ground to allow of the ready exit of the moth. At the bottom, the tube is somewhat more enlarged, and here the larva sheds its skin and enters the quiescent pupal stage. There is considerable variation in the method of pupation, depending on the character of the soil, and not infrequently this stage may be entered within the ear of corn or the cotton boll in which the larva was feeding. The pupal stage during summer lasts from nine to twelve days.

The adult.—The parent moth, like the larva, is extremely variable in general color, ranging in different individuals from a dull ochre-yellow to a dull olive-green. The wing expanse is about 1½ inches, and the body is about seven-eighths of an inch in length. The males may be most readily distinguished from the females by the stouter abdomen of the latter. The accompanying illustration (fig. 2) shows the bollworm moth in a rather characteristic position, and will aid in its identification, where help is needed.

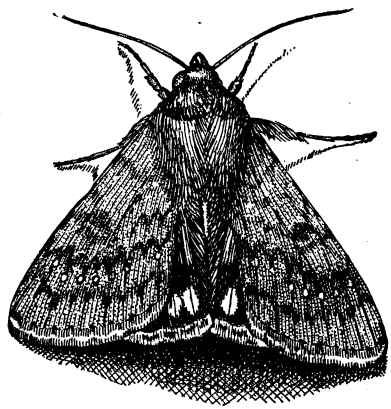

FIG. 2.—Bollworm moth in natural position, wings folded; about twice natural size (original).

Life cycle.—From the above statements as to the length of the respective stages, it is seen that the insect may go through all of its transformations from egg to adult, during summer, in about twenty-three to thirty days. The average of six individuals reared during June and July, at Victoria, Tex., was twenty-eight days. During spring and fall the rate of development is much slower. The average time for the complete life cycle of nine individuals during the spring at Victoria was forty-four days.

FOOD PLANTS.

The bollworm is practically omnivorous, and the list of plants upon which it has been found feeding is very large. In the United States it is destructive principally to corn, cotton, tomatoes, and various garden crops. The combined annual loss from this species in this and foreign countries must be very great, and easily places the bollworm among the foremost injurious insects of the world.

NUMBER OF GENERATIONS.

The number of annual generations of the bollworm in the cotton belt varies from about four to seven, depending on the latitude, with an average of about five. Owing to the irregularity in time of appearance of moths from the ground in the spring and the variation in rate of growth of different individuals from various causes, there results a considerable breaking up of generations, so that these are rarely marked. Thus, in 1903, in Texas, the insect in all stages, from egg to adult, was to be found in considerable numbers in the same field at any given time throughout the season. This condition, however, may have been due in part to the lateness of the season. Furthermore, there may be numerous distinct generations in the same locality, or even on the same plantation, depending on the relative age of the different fields of corn. It is therefore evident that in considering the generations of the bollworm only the majority of the individuals may be referred to.

In general, the moths are out in maximum numbers in the spring in any locality in the cotton belt at a time when field corn is mostly from 8 to 20 inches high, and they deposit by far the greater part of their eggs on these plants. The first generation of bollworms feeds mostly on the tender central roll of leaves of the young corn, the moths from these larvæ appearing during late May or early June. These likewise oviposit largely on corn, which by this time may be commencing to tassel somewhat and to show young ears, the larvæ feeding on the buds, unfolding tassels, and forming ears, as the case may be. Moths from this, the second, generation of larvæ make their appearance from late June until early July and deposit eggs on corn, especially on the silks, which are now appearing quite generally. The third generation of bollworms infests the soft milky ears of corn during early July, and the moths appear again late in July or early in August. By this time, however, the corn throughout the country has begun to dry and the ears to harden and is no longer attractive to the moths for egg laying. They therefore fly to neighboring cotton, from which they secure nectar as food, and on which they deposit the greater part of their eggs. The more or less simultaneous hardening of corn during late July results in a general migration of the moths to the cotton fields, and injury to cotton during August from the fourth generation of bollworms may often be very extensive. Not infrequently, however, cotton may be severely ravaged by the fifth generation during late September or early October. Larvæ of the fifth generation attain full growth usually by the middle of October, burrow into the ground, and transform to pupæ, in which condition the majority remain during the winter, the moths appearing the fol-

lowing spring in time to oviposit on young corn. If, however, the autumn is warm, a small proportion of the pupæ may transform to moths, which oviposit again on cotton, and a few bollworms are thus to be found in cotton fields until the plants are destroyed by frost. It is supposed that a few of the late-appearing moths may hibernate as such during the winter, and hence appear early in the spring, thus adding to the confusion of generations, but the evidence on this point is far from satisfactory.

THE BOLLWORM ON CORN.

Corn is, without doubt, the preferred food of the bollworm, and material injury to cotton occurs only after the corn has become too old to furnish suitable food. A consideration of the bollworm on cotton, therefore, requires brief mention of its occurrence on corn.

The eggs are deposited quite promiscuously over the plant. On young corn the distribution of eggs is confined largely to the leaves, and as many as twenty to twenty-five may often be counted on a single small plant. On corn in tassel and fresh silk, eggs are deposited quite generally over these parts, and the number which may be deposited on a single plant is often surprisingly large.

Notwithstanding the large number of eggs which may be deposited on corn, only a small proportion of the larvæ from these ever reach full growth. Larvæ hatching from eggs laid on other parts of the plant than the silks will mostly perish in their search for suitable food; while, owing to their cannibalistic habits, from the numerous eggs deposited by the moths on the fresh silks, not more than two or three larvæ will succeed in attaining maturity in the same ear. Corn, in addition to being an excellent trap crop to attract moths away from cotton, also serves to reduce the insects in numbers.

Injury to young corn by the first generation is confined largely to the "bud," and becomes apparent as the more central, ragged, and shot-holed leaves unfold (fig. 3). It is rarely serious in extent. Injury by an allied species, the fall army worm (*Laphygma frugiperda* S. & A.) is often very severe on June corn planted in early summer, and has been erroneously attributed to the bollworm. Likewise, injury by the second generation of bollworms is comparatively insignificant, but the third generation, affecting roasting ears, may be the cause of much loss. Injury is not confined to the quantity of kernels of corn eaten, which in the aggregate must be considerable, but more important damage results from the molding and souring of the ear, favored by the filthy excrement and exuded milky juices from the injured grain (fig. 4). No practical means, aside from late fall or winter plowing, have, as yet, been discovered for reducing bollworm injury to corn.

THE BOLLWORM ON COTTON.

Noticeable injury to cotton usually begins with the August generation of larvæ. A few bollworms may have been found in cotton

FIG. 3.—Young corn plant showing injury to "bud" by bollworm—natural size (original).

earlier in the season, but the amount of injury done by these is of comparatively little importance.

Eggs are deposited more or less generally over all parts of the plant. The bollworm on hatching will usually at once devour the eggshell from which it has just escaped. If the place of its birth be on a bud, square, or flower, it may soon penetrate within. If on a leaf, stem, or petiole, it soon begins to crawl up and down, here and there, over the plant, searching for the tender buds or squares. In the course of this more or less aimless wandering from one leaf or part to another, it feeds freely enough to insure its death if poison be present on the plants. The average distribution of eggs over the cotton plants, therefore, has an important bearing on the subject of bollworm control by the use of poisons.

FIG. 4.—Roasting ear infested by bollworm—natural size (original).

During August, 1903, moths were watched late in the evening while they were ovipositing on cotton, and an accurate record was made of the number and distribution of the eggs placed on the plants. The combined record of the eight moths observed is as follows:

Distribution of bollworm eggs on cotton plants.

Eggs deposited on—	
Leaves, upper surface	40
Leaves, lower surface	44
Squares	35
Flowers	11
Leaf stalks (petioles)	11
Stems	15
Bolls	5
Weeds in cotton field	27
Total number of plants deposited on	63

This shows that out of a total of 161 eggs placed on the different parts of the cotton plants, 84, or 52 per cent, were deposited on the leaves. The eggs placed on leaves, leaf stalks, stems, and weeds may be considered in practically the same class with respect to the susceptibility of the resulting larvæ to poisons, and the percentage is thus raised from 52 to approximately 73.

The combined result of the examination of eight cotton plants for bollworm eggs, taken at random in a typical field, is as follows:

Distribution of bollworm eggs on plants.

Eggs found on—	
Leaves	23
Squares	15
Flowers	0
Leaf stalks (petioles)	2

By this method it is shown that approximately 65 per cent of the eggs found on the plants was on other parts than the squares, flowers, and bolls.

FIG. 5.—Normal cotton square at left; flared square at right, due to bollworm attack—natural size (original).

Bollworm injury to cotton squares is quite characteristic and is not likely to be confused with that of any other insect, except, possibly, with that of *Thecla pœas*. The injury done by this latter species is, however, comparatively insignificant. The usual effect of bollworm injury on the squares is to cause them to "flare" and to drop (fig. 5). But there are other causes which bring about this "flaring" and drop-

ping of the squares, as injury by the boll weevil and the punctures of the sharpshooter and other sucking insects. Under certain climatic conditions, as extremes in rainfall and drought, the plant may of itself throw off a considerable number of squares and young bolls. Much of this shedding, whatever the cause, is attributed by planters to the bollworm, and the insect is thus frequently charged with damage greatly out of proportion to the real injury inflicted.

Injury to the boll is likewise easily recognized (figs. 6 and 7). A circular hole is eaten into the boll, usually near its base, of sufficient size to admit the body of the larva. The worm may simply penetrate the boll, leaving it for another, or it may eat quite to the interior and devour more or less of the contents. An individual bollworm may traverse a plant many times in its search for food, or even leave the plant. The traveling may be done during any part of the day, though it is to be noted that the hot sun is avoided as much as possible. The amount of damage done by a single larva is quite variable and hard to determine. The worm may find a suitable boll and largely devour it, or a considerable number may be eaten into, one being left for another on account of its hardness or for other reasons. When feeding on squares, a large number of these must necessarily be devoured, by reason of their small size, to furnish the food required for the larva in its growth.

FIG. 6.—Cotton boll, showing mode of attack by bollworm from without—natural size (original).

The moths or parents of the bollworm are largely nocturnal in their habits, beginning to feed, and the females to oviposit, about twilight, yet it is to be noted that in times of abundance, as during August, many moths may be seen feeding and ovipositing during almost any part of the day, but especially in the afternoon if the sun be more or

less clouded. The principal food of the moths in cotton fields is the nectar secreted by the glands at the base of the bracts surrounding the squares and flowers. Many moths are doubtless attracted to cotton fields on account of the abundance of nectar, and we have the unusual condition in Nature of a plant attracting its own worst enemy.

FIG. 7.—Opened boll to show bollworm at work within—natural size (original).

It is difficult to determine the number of eggs deposited by a moth under normal conditions in the field. In the laboratory at Victoria moths kept in confinement and fed on sugar water averaged about 1,200 eggs each, with a range of from 900 to about 2,200. This is a considerably larger number than has heretofore been accredited to this species. Estimating that only 10 per cent of the 1,200 eggs hatch, and that of this number one-half will produce females capable of laying eggs, the progeny of one moth appearing in spring by the fourth, or August, generation would be 25,920 bollworms, and by September, or the fifth generation, the number would be 155,520. It is thus readily understood how, under favorable conditions, the bollworm may become so numerous and destructive.

SOME FACTORS WHICH TEND TO KEEP BOLLWORMS REDUCED.

Owing to their habits of feeding more or less protected from the attack of parasitic and predaceous insects, bollworms enjoy considerable freedom from important natural checks. The eggs are freely parasitized by a small hymenopterous insect, during certain periods from 50 to 75 per cent being thus destroyed. The larvæ are preyed upon by several species of wasps, and also by ants, which do considerable good in this way. They are parasitized by certain Tachina flies, and succumb in considerable numbers at times to a bacterial disease. During the spring and fall, when the variation in temperature is greater, many bollworms die of this disease before entering the soil to pupate, or shortly afterwards.

Under this heading may also be mentioned the cannibalistic habits of the bollworms themselves. Of the many small larvæ which may be found in a recently silked ear of corn, rarely more than two or three will escape being devoured by their larger fellows, and succeed in reaching maturity. Weather conditions also exert an important influence on this species. In general, rains late in July and early in August favor bollworm injury. Bollworms, along with insects in general, are food for many species of birds and for barnyard fowls. At Calvert, Tex., the present year a flock of turkeys was observed feeding on bollworms infesting alfalfa. The distended crops of the turkeys of the entire flock gave evidence of the considerable number of larvæ which they had eaten during the morning.

INEFFECTIVE METHODS OF BOLLWORM CONTROL.

During periods of serious bollworm injury various methods are often resorted to by planters in their efforts to prevent the destruction of the crop. Some of these do little, if any, good and, as a rule, result only in a waste of time and money. Attention is called to the more common of these, in order that this needless loss may not occur in the future.

LIGHTS FOR TRAPPING MOTHS.

Various light traps have often been advised, and reports are not wanting as to their efficiency. Nevertheless the careful investigation of this subject by this Division has shown that the use of lights for attracting and destroying bollworm moths is without beneficial results. It is true that bollworm moths have been captured at lights, but these have been few in number and mostly males or worn-out females. Numerous species of moths and other insects may be caught, often in large quantities, by lights placed in cotton fields. A careful examination of the catch, however, will show comparatively few bollworm moths. The other insects caught include many that are beneficial by preying upon injurious species. There can be no doubt that money expended in the use of light traps is entirely lost.

POISONED SWEETS.

The use of poisoned baits, as vinegar and molasses poisoned with cobalt to attract the moths in feeding, has been more or less recommended for many years. The practice has been to pour out the bait on plates, placing them on small stakes set up here and there in the cotton field. Experiments the past year with poisoned baits have given no results of material value in bollworm control, though in times of scarcity of food the moths might be attracted in greater numbers. On the whole the method has nothing to recommend it.

BURNING SULPHUR IN COTTON FIELDS.

This appears to be a comparatively recent practice. Burning sulphur is hauled through the cotton fields between the rows on small sleds. Considerable sulphur was used in this way during August of the past year. Its advocates claim that the fumes of the sulphur drive the bollworm moths out of the field. The experiments of the writer with burning sulphur in cotton fields, in 1903, do not indicate any possible benefit from its use. Bollworm and cotton caterpillar moths are often frightened from the plants, but usually fly only a short distance before darting among the plants again. The simple walking between the rows would disturb the millers almost as much, and the recommendation has no valid foundation.

RESISTANT VARIETIES.

The idea of making a crop of cotton ahead of the bollworm by the early planting of early varieties has, to a limited extent, been confused with the idea of immunity on the part of the varieties recommended. It should be stated that, so far as known, there are no varieties of cotton immune to attack by the bollworm. It will be remembered that, in regard to its feeding habits, this insect is practically omnivorous, and it is not likely that it would be deterred by the slight differences occurring in the different varieties of cotton.

FIELD EXPERIMENTS IN 1903.

The field experiments of the Division of Entomology with the bollworm during the past season were conducted along the following lines:

(1) To determine the possibility of making a crop of cotton before the period of greatest bollworm injury by the early planting of an early-maturing variety of cotton, aided by thorough cultivation.

(2) To determine the value in bollworm control of spraying or dusting cotton with arsenical poisons.

(3) To determine the value of corn as a trap crop in protecting cotton from bollworm injury.

Incidentally, tests were made of light traps, poisoned sweets, fumigation of fields with sulphur, and methods of similar character.

CULTURAL METHODS.

The more or less general rains which prevailed in Texas during the winter and early spring of 1902–3 delayed the planting season, which was everywhere from about four to six weeks late, and in this important respect conditions were unfavorable for the experiments involving the early planting of cotton.

The accompanying diagram shows the arrangement, treatment of, and yield from the respective plats in the experiment acreage located on the plantation of Capt. B. D. Wilson, at Hetty, Tex. The plats

were located on fairly uniform rich "second-bottom" soil, capable of producing during favorable seasons about 1 bale of cotton to the acre. Bollworms had been especially destructive to the cotton grown on this land the year previous. According to Captain Wilson, their injury on the plantation during 1902 was such that from 850 acres planted in cotton only 28 bales were gathered.

Experimental cotton plats of the Department of Agriculture at Hetty, Tex., 1903.

Plat 1. 5 acres. King seed. Planted May 1. Thorough cultivation. Yield, 6,741 pounds seed cotton, or 1,348.20 pounds per acre.			Plat 5. 5 acres. Gin seed. Planted May 1. Replanted May 20. Thorough cultivation. Yield, 938 pounds seed cotton, or 187.60 pounds per acre.
Plat 2. 5 acres. King seed. Planted May 1. Average cultivation. Yield, 5,020 pounds seed cotton, or 1,004 pounds per acre.			Plat 6. 5 acres. Gin seed. Planted May 1. Replanted May 20. Average cultivation. Yield, 887 pounds seed cotton, or 177.40 pounds per acre.
Plat 3. 5 acres. King seed. Planted June 1–2. Thorough cultivation. Yield, 1,804 pounds seed cotton, or 360.80 pounds per acre.		Turn row.	Plat 7. 5 acres. Gin seed. Planted June 1–2. Thorough cultivation. Yield, 692 pounds seed cotton, or 138.40 pounds per acre.
Plat 4. 5 acres. King seed. Planted June 1–2. Average cultivation. Yield, 1,379 pounds seed cotton, or 275.80 pounds per acre.			Plat 8. 5 acres. Gin seed. Planted June 1–2. Average cultivation. Yield, 647 pounds seed cotton, or 129.40 pounds per acre.

It will be noted that the scheme includes the comparison of an early-maturing variety of cotton (King) with cotton grown from common

gin seed; of early and late planting; and of thorough with average cultivation under both of the above conditions. By thorough cultivation is meant five to six plowings with three or four choppings, and by average cultivation, three to four plowings with two or three choppings. The rows were 5 feet apart and the plants were chopped to 30 inches in the row.

It was desired to determine by comparison the relation of these several methods of treatment to the production of cotton during a season of severe bollworm injury. Fortunately, from an experimental standpoint, this insect was quite numerous and destructive in these plats, and on the plantation generally, during August and the first half of September, and the results obtained, therefore, bear directly on the question of the possibility of reducing bollworm injury by cultural methods.

The considerable difference in yield to be noted between the King plats and the plats planted to common gin seed must, in fairness, be attributed in part to the abnormal lateness of the season. While a full growing and fruiting season was afforded the early-maturing variety, the later common gin seed cotton was cut off by frost. The latter, with an average season, would no doubt have matured a considerably larger crop.

In the comparisons between plats 1 and 5 and between plats 2 and 6 it should be noted that plats 5 and 6 were entirely replanted twenty days later than date of first planting, so that these plats were in fact planted rather late instead of early. But the necessity for replanting was due entirely to the inferiority of the common gin seed to the King seed. The superior vitality of the King seed resulted in a satisfactory stand under the adverse weather conditions then prevailing, whereas the gin seed germinated very poorly. The results are in full accord with the observations made on the respective plats throughout the season. Plats 1 and 2 suffered much less from bollworms during August and September by reason of their more matured condition than did the other plats. The injury was most marked on the late fruiting and comparatively unprolific plants from native gin seed, and a considerable part of the reduction in yield must be attributed to this fact.

For ready comparison the more important results of the experiments at Hetty are shown in the following statements:

Early-maturing variety versus native gin seed.

Yield per acre with early-planted King seed and thorough cultivation, pounds seed cotton	1,348.20
Yield per acre with early-planted native gin seed and thorough cultivation, pounds seed cotton	187.60
Yield per acre in favor of King seed ..... pounds seed cotton	1,160.60
Value of excess per acre, at 3 cents per pound of seed cotton	$34.81

Early-planted King seed, with thorough cultivation versus late-planted native gin seed with average cultivation.

Yield per acre with early-planted King seed and thorough cultivation, pounds seed cotton	1,348.20
Yield per acre with late-planted native gin seed and average cultivation, pounds seed cotton	129.40
Yield per acre in favor of early-planted King seed with thorough cultivation ..... pounds seed cotton	1,218.80
Value of excess per acre, at 3 cents per pound of seed cotton	$36.56

Early planting with thorough cultivation versus late planting with thorough cultivation.

Yield per acre with early-planted King seed and thorough cultivation, pounds seed cotton	1,348.20
Yield per acre with late-planted King seed and thorough cultivation, pounds seed cotton	360.80
Yield per acre in favor of early planting ..... pounds seed cotton	987.40
Value per acre in favor of early planting, at 3 cents per pound of seed cotton	$29.62

Thorough cultivation versus average cultivation.

Yield per acre with early-planted King seed and thorough cultivation, pounds seed cotton	1,348.20
Yield per acre with early-planted King seed and average cultivation, pounds seed cotton	1,004.00
Yield per acre in favor of thorough cultivation .. pounds seed cotton	344.20
Value of excess per acre, at 3 cents per pound of seed cotton	$10.32

Early planting with thorough cultivation versus late planting with average cultivation.

Yield per acre with early-planted King seed and thorough cultivation, pounds seed cotton	1,348.20
Yield per acre with late-planted King seed and average cultivation, pounds seed cotton	275.80
Yield per acre in favor early planting and thorough cultivation, pounds seed cotton	1,072.40
Value of excess, at 3 cents per pound of seed cotton	$32.17

ARSENICAL POISONS.

Although poisons have long been recommended for bollworm control on cotton, their use has not been adopted to any extent. This may have been due to the fact that their value in this particular had not been demonstrated in any such way as to furnish tangible results. The possible usefulness of poisons is based on facts connected with the early life of the bollworm, not ordinarily taken into consideration by planters. Bollworms are not usually noticed until they have begun to bore into the squares, flowers, and bolls, and the application of poisons at this time manifestly appears to be of little use.

It has already been shown (page 14) that from 65 to 73 per cent of the eggs deposited by bollworm moths on the cotton plant, are so

placed that the resulting larvæ would be more or less subject to poisoning, if poisons were present on the plants. As bearing on this point the following experiments are of interest:

During June, a cotton plant bearing numerous squares, flowers, and bolls, was sprayed with Paris green at the rate of 1 pound to 100 gallons of water. A few hours later 100 larvæ, just hatched, were distributed over the plant, which was then covered with a large wire-screen cage for protection. Subsequent examinations did not reveal any bollworms whatever on the plant, the larvæ doubtless being all destroyed by the poison.

A similar test was made during August, but only 50 young larvæ were used. Out of this number but one bollworm survived, which was found when about two weeks old feeding on a half-grown boll.

Field experiments with poison were conducted at Hetty and at Calvert, Tex., and, although started somewhat late, nevertheless gave decidedly favorable results.

At Hetty, a 10-acre cut of uniform, late, native cotton, growing on bottom land, was selected, 5 acres of which was poisoned and 5 acres was left unpoisoned, as a basis for comparison. Paris green was dusted freely over the plants by the usual dusting method, namely, from bags on the ends of a short pole carried by a man on horseback. Applications were made August 22 and 31 and September 8, using approximately 3 pounds of the "green" per acre at each dusting. The results are indicated in the following table:

Comparison of yields from plat dusted with Paris green and plat left untreated.

Yield from poisoned 5-acre plat	pounds seed cotton	2,720
Yield from unpoisoned 5-acre plat	do	1,434
Yield in favor of poisoning	do	1,286
Value of excess, at 3 cents per pound of seed cotton		$38.58
Cost of 45 pounds of Paris green, at 18 cents per pound		$8.10
Cost of labor, one man three mornings, at 50 cents per morning		1.50
Total cost of poisoning		9.60
Net gain per acre in favor of poisoning		5.79

At Calvert poisons were applied by the dusting method and also by means of a spray pump. The spraying was done with a barrel sprayer furnished with two leads of hose and four nozzles. A team, wagon, and two men were required, one man to drive and pump, the other to handle the nozzles at the rear end of the wagon. "Green arsenoid" was used, at the rate of 1 pound to 50 gallons of water, which would poison approximately 1 acre. With water one-half mile distant, only 5 to 6 acres per day could be sprayed. With a more convenient water supply and with geared spraying machinery, the ground covered per

day, could, no doubt, be considerably increased. Below is the treatment given and the results from the respective plats:

Comparison of yields from plat sprayed with "green arsenoid," plat dusted with Paris green, and plat left untreated.

Plat I, 3.89 acres, left untreated for comparison; yield of seed cotton per acre ..... pounds..	246.0
Plat II, 4.37 acres, treated with "green arsenoid," 1 pound to 50 gallons water; sprayed August 14, 28, and September 5; yield of seed cotton per acre, pounds	554.8
Increased yield of seed cotton per acre in favor of spraying..pounds ..	308.8
Value of gain per acre, at 3 cents per pound of seed cotton	$9.26
Cost of three sprayings per acre, including labor and poisons	2.27
Net gain per acre in favor of spraying	6.99
Plat III, 4.38 acres, dusted with Paris green, average of 3 pounds per acre; poisoned August 15, 22, and September 4; yield of seed cotton per acre, pounds	460.21
Increased yield of seed cotton per acre from poisoning .....pounds..	214.21
Value of increase per acre, at 3 cents per pound of seed cotton	$6.42
Cost of three dustings per acre, including labor and poisons	1.98
Net gain per acre from poisoning	4.44

CORN AS A TRAP CROP.

Attention has already been called to the fact that corn, when in a suitable condition, is the preferred food of the bollworm, and that cotton is not materially injured until after the corn has begun to harden. It would therefore appear that bollworms might be largely kept out of cotton by the proper use of corn as a trap crop. The use of corn in this way has been frequently recommended by this Division, and instances are not wanting where good results have been secured. Nevertheless, for reasons not apparent, this expedient has been but little adopted.

Extensive tests of corn as a trap crop in protecting cotton from bollworm injury were made the past year, both at Calvert and at Willspoint, Tex. Unfavorable weather and soil conditions, however, necessitated considerable change in the original plans, and it was possible to have corn in silk for the August generation only. But it is usually this generation that causes the greatest injury to cotton, and the control of which is especially important. It is not permitted, as in the experiments previously reported, to indicate the value of the trap crop in pounds of seed cotton, as it is manifestly impossible to arrange a control plat which would meet the necessary condition of adjacent location to the plat under test, and at the same time be entirely free from the protective influence of the corn. Bollworm moths fly about freely in the cotton fields and would be attracted a considerable

distance by the trap crop. Its value, in fact, depends to a considerable extent on this migratory habit of the moths.

The experiments in question, as finally arranged, provided for belts of corn around and through the cotton fields, planted so as to be in prime silking condition about August 1. By this means, the large generation of moths appearing in late July and August, from larvæ infesting roasting ears in the surrounding cornfields, was largely detracted from the cotton, and egg-laying was concentrated on the trap rows of corn. The number of eggs found on a single corn plant was often surprisingly great. Thus, in the trap rows at Willspoint during early August, when the moths were out in large numbers, 804 bollworm eggs were counted on a single corn plant, and the average of eight typical plants at this time was 495 per plant, distributed as follows: 175 on the leaves, 45 on the leaf sheaths, 120 on the tassels, and 155 on the silks. Furthermore, the trap rows of corn were attractive to the moths all through the season, from the time the plants were from 12 to 18 inches high until ripening began. The total number of eggs deposited on a plant during its entire period of growth must be very great, and a simple calculation will indicate the enormous number of bollworm eggs that are kept from cotton by a series of belts of corn planted through the cotton field.

It might be supposed that, by thus furnishing the insect with its favorite food, its increase and consequent greater destructiveness would be the result. This, however, is not the case. From the several hundred eggs that may be found on a single corn plant but two or three larvæ will eventually succeed in attaining their growth, owing to the cannibalistic habits of the larvæ themselves, and for other reasons already pointed out.

SPECIFIC RECOMMENDATIONS.

The earlier investigations of the Division of Entomology and its work the past season warrant the recommendation of the following methods of lessening bollworm injury:

I. Plant an early maturing variety of cotton as early as possible in the spring and give the plants good cultivation. By good cultivation is meant five or six plowings, with three or four choppings. By plowing and cultivating in this way a good crop may usually be insured before the bollworms become destructive in August. In the territory infested with the cotton boll weevil this course becomes doubly necessary, as it is only by such methods that ordinarily a crop of cotton may be made. The possibility of the plants developing a crop after the bollworms may leave is removed on account of the presence of the weevil. Early planting of early maturing varieties will also allow of the crop being gathered much earlier in the fall than is possible with plantings of ordinary gin seed at the usual time. It will thus become possible to a considerable

extent to clear the land of the plants and plow in the fall, which, aside from being good farm practice, will exert a very beneficial influence in controlling the bollworm by breaking open their hibernation cells and exposing the pupæ to the influences of cold and rain during the winter.

The above recommendations involve no outlay of labor and capital not requisite to successful cotton culture, and, furthermore, agree entirely with the best known methods of circumventing the ravages of the Mexican cotton boll weevil. It thus becomes possible to secure the maximum amount of freedom from the depredations of the boll weevil and the bollworm by one and the same course of farm practice.

II. The use of corn as a trap crop may be advantageously combined with the cultural methods indicated above, especially so if it is not found possible to plant early on account of climatic conditions or for other reasons. In planting cotton leave vacant strips across the field every 200 or 300 feet, sufficiently wide for planting 10 or 12 rows of corn. These strips should be planted with corn so that it will be in prime silking condition not later than August 1. Under favorable conditions of rainfall and with good cultivation, Mexican June corn planted by June 1 will be tasseling and silking freely by August 1. Plant cowpeas in the corn belts, so that the plants will be flowering along with the appearance of the tassels and silks on the corn. The cowpeas are to furnish food for the moths and will largely prevent their going to the cotton for food and depositing thereon a certain proportion of their eggs. The corn may be allowed to mature and may be harvested in the usual way. Sufficient corn may be grown in these belts to meet a portion of the needs of the plantation and at the same time afford material protection to the cotton crop from bollworms. As will at once appear, *the planting of corn through the cotton field at the usual time in the spring is bad practice from a bollworm point of view.* With the hardening of the corn during July the insects turn their attention to cotton. The trap rows of corn should not be tasseling and silking before about August 1.

III. Experiments with poisons the past year indicate that these may be profitably used in lessening bollworm injury to cotton. The poisons should be applied to the plants in time to insure the destruction of the maximum number of young larvæ of the August generation. In general, this will be about August 1. When it is noticed that the moths are becoming abundant in the cotton fields the first application should be made, and a second application should follow a week or ten days later. The occurrence of even a moderate rain shortly after the poison has been applied will necessitate another application if best results are to be secured. If conditions are favorable for bollworm injury poison should be used again about September 1 in time to check injury from the September generation of larvæ. In the work of poisoning special pains should be taken to cover all parts

of the plant as nearly as possible. The poisons should be distributed much more generally over the plant than is necessary for the cotton caterpillar.

Of the modes of applying the poison little need be said. The general use of poisons against the cotton caterpillar has familiarized most planters with the details of this work. In point of convenience the dusting method is to be recommended. If an abundance of water is at hand, suitable spraying machinery may be used. The amount of poison used in the dusting method will be greater than that required to poison an equal area by spraying, but in dusting there will be a saving in labor and machinery, and what is more important, the work may be done more rapidly. The question of how to apply the poisons most economically, and in a way to secure the best results, should be settled by each planter according to his conditions. If the work be done with spraying machinery, a poison, such as Paris green, should be used at the rate of 1 pound to every 50 gallons of water, and if the dusting method is adopted, from 2 to 3 pounds will be required per acre for each application.

In conclusion, attention should be called to the entire practicability of the methods recommended. They may be used singly, or any two may be employed, as the early planting of early varieties, supplemented by the use of poisons or trap crops; or all three may be employed in conjunction, and, if properly managed, should give a large degree of freedom from bollworm injury.

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